ESPR Subject Area 5 'Environmental Microbiology, (Bio)Technologies, Health Issues'

Jean-Paul Schwitzguébel (Principal Subject Editor for Area 5)

Subject Editor for Area 5.3: Phytoremediation and ecosystem restoration

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Profile

Dr. Jean-Paul Schwitzguébel is a plant and microbial biochemist. After his studies at the University of Geneva, he worked as a postdoctoral researcher at the Swiss Federal Institute of Technology (ETH) in Zurich, at the Imperial College of Science and Technology in London (UK), and at the University of Neuchatel, focusing on the metabolism and bioenergetics of higher plants and microorganisms. He moved then to the Swiss Federal Institute of Technology at Lausanne (EPFL) as a permanent senior scientist in the Laboratory for Environmental Biotechnology. Most of his work is now devoted to research and development in the fields of phytoremediation and bioenergy [1–5]. He is also the initiator and coordinator of the European COST Actions 837, from 1998 to 2003, (http://lbewww.epfl.ch/COST837) and 859, from 2004 to 2009, (http://www.gre.ac.uk/cost859/) on phytotechnologies to promote sustainable land use and improve food safety.

The challenges I have identified for Subject Area 5.3 and the actions to be done

Green plants can be used to accumulate toxic metals and organic pollutants from contaminated soils and water for cleanup purpose, to prevent further degradation of our environment and to remediate the damage caused by the increasingly industrialized society. The use of plants specifically chosen or tailored for the rehabilitation of polluted land and brownfields, water purification, and even removal of indoor or outdoor air contaminants, is becoming essential to achieve sustainable development. Plants represent a more environmentally compatible and less expensive method to site restoration compared to physico-chemical and engineering approaches, even if the time scale required to reach the target end-points is sometimes a limiting factor. Plants are already cleaning our environment constantly, everywhere, acting as '**green livers**', even if we do not recognize or know it.

According to the United Nations Environment Programme, "phytotechnologies are ecotechnologies relating to the use of vegetation, to resolve environmental problems in a watershed management, by prevention of landscape degradation, remediation and restoration of degraded ecosystems, control of environmental processes, and monitoring and assessment of the environmental quality". Phytotechnologies exploit natural processes and can be used for revegetating degraded lands (such as quarries, road sides), removal of excessive nutrient loads (phytoamelioration) and the cleanup of wastewater (e.g. road runoff, municipal and industrial effluents, surface and seepage water) using soil-plant filters, buffer strips or constructed wetlands (phytoprevention). Phytotechnologies are beginning to offer efficient tools and environmentally friendly solutions for the cleanup of contaminated sites and water, the improvement of food chain safety, and the development of renewable energy sources, contributing to a sustainable use of water and land.

Worldwide a significant part of **agricultural land** is contaminated with toxic metals and organic pollutants, some of which still is in agricultural use. Food crops produced on those sites can pose human health risks: several important agro-ecosystem functions are impaired and those sites can be sources of food chain contamination and further pollution via re-spreading of metals and other pollutants to the surroundings by wind- and water erosion or leaching into groundwater. As a consequence, contaminated agricultural soils still under production and many additional areas, not yet subject to regulation, will be taken out of food production and become marginalised. There are two alternatives to deal with this land: either it has to be set aside or to be cleaned. Conventional remediation methods like landfilling or excavation and extraction impose high costs, destroy soil structure, and diminish soil productivity. Phytotechnologies offer a cost-effective *in situ* alternative for low- or medium-contaminated soils resulting in increased soil fertility.

Brownfields – contaminated sites around former and present mines, abandoned old industrial sites, ash and slag dumps from coal-fuelled power plants, coal and gas plants, oil-refineries, ammunition plants, military bases, and pesticide tombs – are numerous and their restoration for future safe use has become an important issue. An appropriate rehabilitation and sustainable management of contaminated brownfields will thus be a priority task in the near future. Phytotechnologies are expected to play a major role in the remediation of former industrial areas, but the activities should include site identification and characterization, parallel soil treatability tests, as well as field-scale implementation and evaluation.

Green plants can also be used to treat freshly dredged polluted **sediments**, even if this approach is only at its infancy in Europe at the present time.

In constructed wetlands (reed bed), plants are used as part of a managed ecosystem to remediate contaminants from **aqueous waste streams**; they can be operated as surface (free floating, emergent or submerged plants) or sub-surface (horizontal or vertical) flow systems. Alternatively, hydroponic cultures or nutrient film techniques can be used. Pollutants can also be removed from aqueous solutions by biosorption on plant biomass and agricultural waste. Waters under consideration include industrial and domestic wastewater, ground- and surface water, as well as landfill leachates, contaminated with organic pollutants, toxic metals or radionuclides.

Nowadays, the use of plants for the removal of **atmospheric contaminants** other than CO_2 is less developed, but it will become relevant to sustainable development and human health. There is thus an urgent need to study for example the carbon fluxes and volatile organic carbon and nitrogen oxides emission, especially under urban and industrial conditions. Plants can be selected to remove/reduce pollutants present in indoor and outdoor air, including those relevant to global warming.

Phytoremediation can be based on:

- **Phytoextraction**, the absorption of mineral or organic contaminants into plant roots, then translocation into shoots; the harvest and destruction of the plants can be followed by recycling strategies (metals) of the contaminated biomass or ash.
- **Phytodegradation and phytotransformation** of organic pollutants, exploiting the huge potential and biodiversity of plant metabolism.
- **Phytostimulation,** where plant root exudates enhance microbial metabolism in the rhizosphere; plant/microbial interactions are important for such a process.
- **Phytostabilisation**, which implies the immobilisation of contaminants through mechanisms such as adsorption to plant roots or soil particles, or precipitation in the root area, thus preventing migration of contaminants in soil, groundwater or air, and decreasing erosion, runoff and leaching. Additionally, it promotes the restoration and biodiversity of ecosystems, or the production of industrial crops.
- **Hydraulic control** of pollutants, i.e. the use of phreatophyte trees (e.g. poplar, willow) to transpire large amounts of water and avoid migration of pollutants.

The main objective of COST Action 859 (http://w3.gre.ac.uk/cost859/) is precisely to boost a European-wide integration and expansion of research and development efforts to use phytotechnologies as instruments for management and removal of environmental contamination, achieving sustainable and viable green solutions. COST Action 859 thus aims to contribute to the implementation, assessment and integration of appropriate and efficient phytotreatments for sustainable land use management, ecosystem restoration and mitigation strategies applicable to different environmental compartments. Two Working Groups provide a better understanding of the absorption/exclusion, translocation, storage and detoxification mechanisms of essential or toxic mineral elements, as well as organic contaminants, at physiological, biochemical and molecular levels. Two further Working Groups aim to improve the food chain safety and to prepare the best use of plants for sustainable land use.

Among others, the following points are of critical importance for the success of phytotechnologies, which are addressed in the framework of COST Action 859 and are also challenges identified in and for this area of ESPR:

- In developing phytotechnologies, pre-harvest parameters (type and degree of pollution, plant selection, treatability, agronomic techniques, groundwater capture zone, uptake rate, transpiration rate, and required cleanup time) and post-harvest evaluation parameters (collection, residues, waste disposal, and contaminated plant material treatment and valorisation, recycling of metals) must be considered as important milestones in their successful implementation. The use of biomass after phytoremediation is suggested, especially as a source of renewable bioenergy (heating, bioethanol, biodiesel, and biogas) or of diverse bio-products.
- The economics of phytoremediation of organic pollutants is generally favourable, but cost is an acute problem for the treatment of heavy metals. Ideally, plants should produce biomass with added value (fibres) or should be used to recover valuable products like oil for lubricants, fragrances or other fine chemicals. Trees used for groundwater cleanup or management of landfill leachates can be harvested and used for paper production. Another option is based on the selective recovery of metals from plant residuals after combustion, which could provide an economically valuable recycled product, depending on the type and concentration of the metal. Via this approach contaminated sites can be cleaned and at the same time farmers are offered sources of income instead of set aside scenarios. This will create new possibilities at urban fringes with demands for sustainable employment in which energy farming can play a more significant role.
- There is also a very real need to develop water cleaning treatments based on the use of green plants (constructed wetlands, hydroponic systems or nutrient film techniques), well integrated in water resource management. Phytotechnologies clearly have a significant role to play in the prevention of pollutants entering the water cycle. Another issue is the removal of new compounds, micro-pollutants with pharmaceutical effects: constructed wetlands will also play a major role in this respect and give significant health benefits in the long-term. Furthermore, the global warming could create severe irrigation problems; therefore it will become critical to treat water in an appropriate way for crop irrigation and constructed wetlands will play a key role for such a purpose in the near future.

My Activities as Submission Editor in ESPR

As Submission Editor in the ESS (Electronic Submission System: http://www.scientificjournals.com/sj/all/ESS), I have successfully guided two papers through the peer-review process to the publication in OnlineFirst. They appear in this issue (Silva et al. 2007, Su et al. 2007).

My activities as Author in ESPR and the closely related JSS

See Courdouan 2004, Gupta and Schwitzguébel 2003, Schröder et al. 2002, Schwitzguébel et al. 2002a,b

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